Optical Generation/Radiative Recombination

The next physical mechanisms we have to consider for generation/recombination are photon transition. This mechanism occurs primarily in one step and is therefore a direct generation/recombination mechanism. There are two partial processes involved. For radiative recombination, an electron loses energy on the order of the band gap and moves from the conduction band to the valence band. For optical generation, an electron moves from the valence band to the conduction. In silicon, band to band generation/recombination is insignificant. This effect, however, is important for narrow gap semiconductors and semiconductors whose specific band structure allows direct transitions. By assuming a capture rate C_c^{OPT} and an emission rate C_e^{OTP}, the involved partial processes can be written as

$$R_{np}^{OPT} = C_c^{OPT} np, \qquad \text{3-339}$$

for recombination and

$$G_{np}^{OPT} = C_e^{OPT} \qquad \text{3-340}$$

for generation.

These rates must be equal in thermal equilibrium so that

$$C_{np}^{OPT} = C_c^{OPT} n_{ie}^2 \qquad \text{3-341}$$

The total band to band generation/recombination is the difference of the partial rates, which equates to

$$R_{np}^{OPT} = C_c^{OPT}(np - n_{ie}^2). \qquad \text{3-342}$$

In ATLAS, C_c^{OPT} and can be defined by COPT on the MATERIAL statement or implemented using a C-Interpreter routine. To turn on the optical recombination/ generation model, define the OPTR keyword on the MODELS statement.

Auger Recombination

Auger recombination occurs through a three particle transition whereby a mobile carrier is either captured or emitted. The underlying physics for such processes is unclear and normally a more qualitative understanding is sufficient [245].

Standard Auger Model

Auger Recombination is commonly modeled using the expression [68]:

$$R_{Auger} = \mathrm{AUGN}\,(pn^2 - nn_{ie}^2) + \mathrm{AUGP}\,(np^2 - pn_{ie}^2) \qquad \text{3-343}$$

where the model parameters AUGN and AUGP are user-definable in the MATERIAL statement (see Table 3-75 for its default value). You can activate this model with the AUGER parameter from the MODELS statement.

Table 3-75 User-Specifiable Parameters for Equation 3-343			
Statement	**Parameter**	**Default**	**Units**
MATERIAL	AUGN	2.8×10^{-31}	cm^6/s
MATERIAL	AUGP	9.9×10^{-32}	cm^6/s

Klaassen's Temperature-Dependent Auger Model

The Klaassen Auger Recombination Model [140] is activated by specifying the KLAAUG parameter of the MODELS statement. The form of this model is

$$R_{Auger} = C_n(pn^2 - nn_{ie}^2) + C_p(np^2 - pn_{ie}^2) \tag{3-344}$$

where the Auger coefficients are temperature dependent according to:

$$C_n = \mathrm{KAUGCN}\left(\frac{T_L}{300}\right)^{\mathrm{KAUGDN}} \tag{3-345}$$

$$C_p = \mathrm{KAUGCP}\left(\frac{T_L}{300}\right)^{\mathrm{KAUGDP}} \tag{3-346}$$

Here, the KAUGCN, KAUGCP, KAUGDN, and KAUGDP parameters are user-definable in the MATERIAL statement and have the defaults shown in Table 3-76.

Table 3-76 User-Specifiable Parameters for Equation 3-345 and 3-346			
Statement	**Parameter**	**Default**	**Units**
MATERIAL	KAUGCN	1.83×10^{-31}	cm^6/s
MATERIAL	KAUGCP	2.78×10^{-31}	cm^6/s
MATERIAL	KAUGDN	1.18	
MATERIAL	KAUGDP	0.72	